GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT INITIATION

Date: 9/26/79

Project Title: Microearthquake Instrumentation & Analysis Between Hartwell and Clark Hill Reservoir Area

Project No: G-35-661

Project Director: Dr. L. T. Long

Sponsor: U.S. Army Corp. of Engineers; Savannah District; Savannah, GA 31402

Agreement Period: From 8/10/79 Until ~~8/9/80~~ 1/31/81 (contract term)

Type Agreement: Contract No. DACW21-79-C-0099 (Fixed Price)

Amount: $16,283.21

Reports Required: Annual Summary Report; Brief Reports on Seismic Activity

Sponsor Contact Person (s):

Technical Matters

Contractual Matters (thru OCA)

Contracting Officer's Representative (COR)

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U.S. Army Corps of Engineers
Engineering District
Savannah, GA 31401

Edward P. Ludwig
Contracting Officer
U.S. Army Corps of Engineers
Savannah District
P.O. Box 889
Savannah, GA 31402

7/28/81

Defense Priority Rating: none

Assigned to: School of Geophysical Science (School/Laboratory)

COPIES TO:

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- Division Chief (EES)
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B-940

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 8/11/81

Project Title: Microearthquake Instrumentation and Analysis Between Hartwell and Clark Hill Reservoir Area

Project No: G-35-661 (followed by G-35-687)

Project Director: Dr. L. T. Long

Sponsor: U.S. Army Corps of Engineers, Savannah District

Effective Termination Date: 1/31/81

Clearance of Accounting Charges: 1/31/81

Grant/Contract Closeout Actions Remaining:

- x Final Invoice and Closing Documents
- _ Final Fiscal Report
- x Final Report of Inventions
- x Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other ____________

Assigned to: Geophysical Sciences (School/~~Laboratory~~)

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ANNUAL REPORT NO. 1
PROJECT NO. G–35–661

MICROEARTHQUAKE INSTRUMENTATION AND ANALYSIS BETWEEN HARTWELL AND CLARK HILL RESERVOIR AREAS

FINAL TECHNICAL REPORT for Period 8 October 1979 – 31 January 1981

By

Dr. Leland Timothy Long
Associate Professor of Geophysics

Prepared for

U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
P.O. BOX 889
SAVANNAH, GEORGIA 31402

May 1981

GEORGIA INSTITUTE OF TECHNOLOGY
A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF GEOPHYSICAL SCIENCES
ATLANTA, GEORGIA 30332

1981

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8 October 1979 - 31 January 1981

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Issued May, 1981
GEORGIA INSTITUTE OF TECHNOLOGY
School of Geophysical Sciences
Atlanta, Georgia 30332

MICROEARTHQUAKE INSTRUMENTATION AND ANALYSIS BETWEEN HARTWELL AND CLARK HILL RESERVOIR AREAS

INTRODUCTION

The Richard B. Russell Lake will cover the Savannah River valley in the Piedmont Province of Georgia and South Carolina from the headwaters of the Clark Hill Reservoir north to Hartwell Dam. Impoundment of the Savannah River is currently anticipated in 1982. While most reservoirs do not trigger microearthquakes when they are first impounded, there is evidence that some reservoirs in the Piedmont Province of South Carolina and Georgia have induced seismic activity. The objective of the microearthquake instrumentation and the analysis of data on events occurring between the Hartwell and Clark Hill Reservoir Areas is to document the seismicity prior to, during and after impoundment of the Richard B. Russell Lake. This first report covers the installation of the seismic monitoring system and the analysis of the data obtained by the seismic monitoring system through 31 January 1981.

SEISMICITY

The earthquakes observed in the Piedmont Province (Figure 1) occur at scattered locations with little apparent correlation with major geologic structures. Where reliable estimates of their depth are available, the implied depths are shallow and are usually less than five kilometers deep. The largest, the Union County earthquake of 1913 was, perhaps, a magnitude 5.5. The rate of activity is low, with an average of one event greater than magnitude 3.5 occurring less than once every four years. Today, the seismicity at magnitudes less than 2.0 is difficult to assess because the shallow focus earthquakes typical of the Piedmont Province generate signatures similar to the signature of industrial explosions in the many quarries which mine the near-surface crystalline rocks. The seismic monitoring system will detect earthquakes or blasts less than magnitude zero. Hence, an initial objective of the analysis is to identify the active quarries and their industrial blast sites in order to properly assess the background level of seismicity.

The area of the Richard B. Russell Lake does not exhibit any historical seismicity, although the area has experienced measurable intensities from more distant events, such as the 1886 Charleston earthquake and the Clark Hill vicinity earthquakes. The two closest epicenters based on currently available data are near Due West and McCormick, South Carolina. Due West is approximately 40 km east of the Savannah River and experienced earthquakes in 1929, 1930, 1931 and 1956. The earthquake near McCormick occurred August 2, 1974. On November 1, 1875, an intensity VI earthquake was noted in the Clark

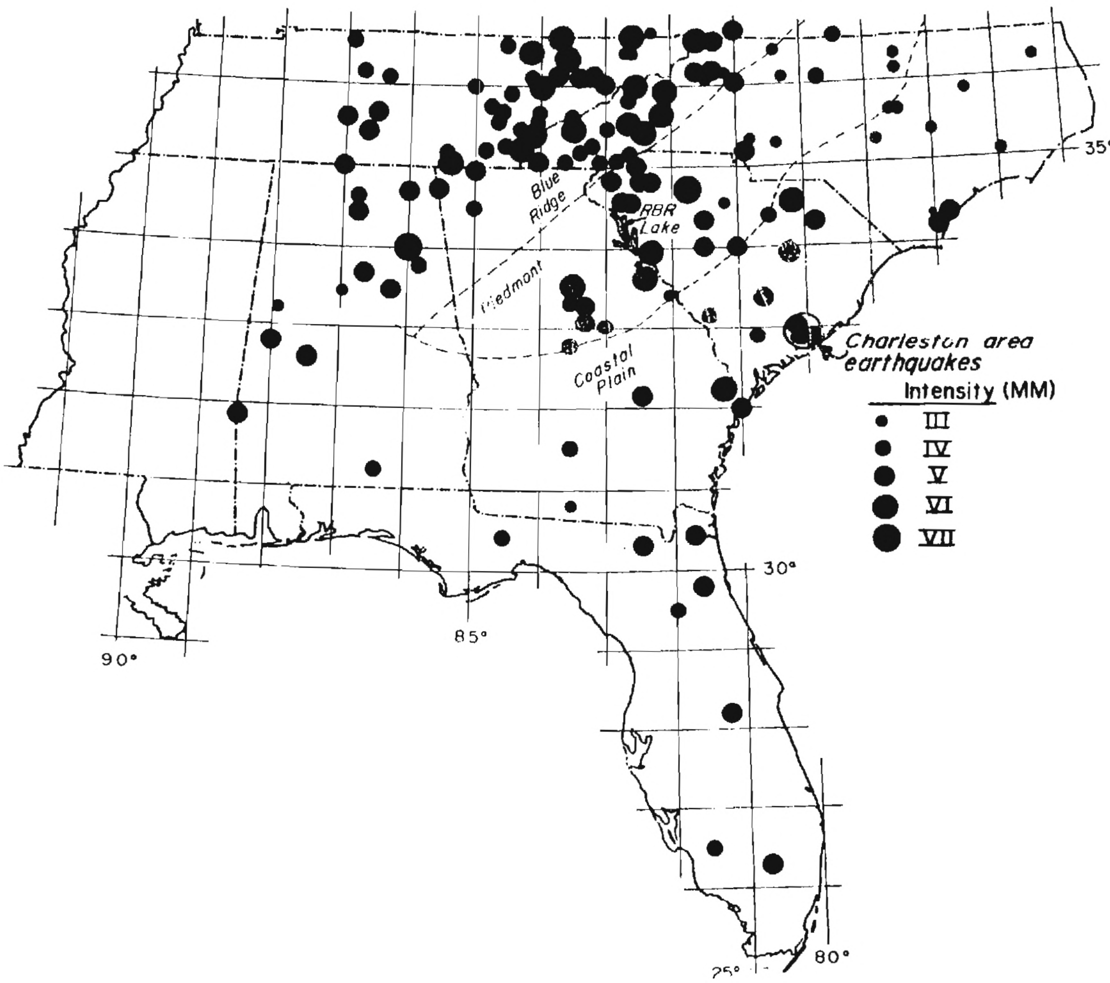


Figure 1. Seismicity of the Southeastern United States and its relation to the proposed Richard B. Russell (RBR) Lake

Hill Reservoir Area near Lincolnton, Georgia. These two events occurred 10 to 20 km south of the Richard B. Russell Dam site.

Many of the recent earthquakes in the Piedmont Province have epicenters near reservoirs. These include the Seneca earthquake July 13, 1971, the Jocassee earthquakes of 1975, 1976 and 1979, and the August 2, 1974 McCormick earthquake. Monticello Reservoir north of Columbia, S.C., triggered an extensive sequence of small (magnitude 2.5 to 3.0) earthquakes. Lake Sinclair, Georgia, has exhibited a continuous sequence of events, although the reservoir was impounded in the 50's and the association with the reservoir is tenuous. Lake Oconee, impounded in the spring of 1979, generated only a short sequence of small (less than $M = 0$) events in the spring of 1980. The Oconee reservoir events would not have been noted without a sensitive seismic net. Hence, one can speculate that other reservoirs similarly triggered events, but these events were undetected. In the case of Monticello and Oconee, seismic monitoring was available prior to loading and no significant seismic activity was detected in the vicinity of the forthcoming reservoirs. While at present the pre-impoundment seismicity does not allow predictions of induced earthquakes, it can provide valuable data concerning the occurrence of natural seismic activity.

The Richard B. Russell Lake will cover a large area of the Piedmont Province, an area in which nearby reservoirs are associated with induced seismic activity. Hence, the probability is high that Richard B. Russell Lake may induce some seismic activity. If seismic activity is induced near the Richard B. Russell Lake, the earthquakes will most likely be small, generally unfelt and less than magnitude 2.5. Earthquakes with magnitudes as large as 3.5 are not common near Piedmont Province reservoirs (only two events with magnitudes greater than 3.2 occurred at Jocassee) and magnitudes larger than 4.5 are highly unlikely. Earthquakes could conceivably be induced anywhere near the reservoir. An objective of the seismic monitoring is to locate sites of activity should they develop after impounding the reservoir. Because their depths are expected to be shallow, perhaps as shallow as 0.5 to 1.5 km, the widely spaced net cannot determine accurate depths of focus. Instead, portable equipment would be deployed with appropriate spacing to compute depths of focus for events in selected active areas.

SEISMIC NET

The Richard B. Russell seismic net consists of three vertical-component short-period seismic systems. The three stations (see Figure 2) form a triangle elongated in the north-south direction. The three sites are furnished and maintained by the Savannah District Corps of Engineers. Maintenance of the microearthquake monitoring system is provided through the mutual support of Georgia Tech and the

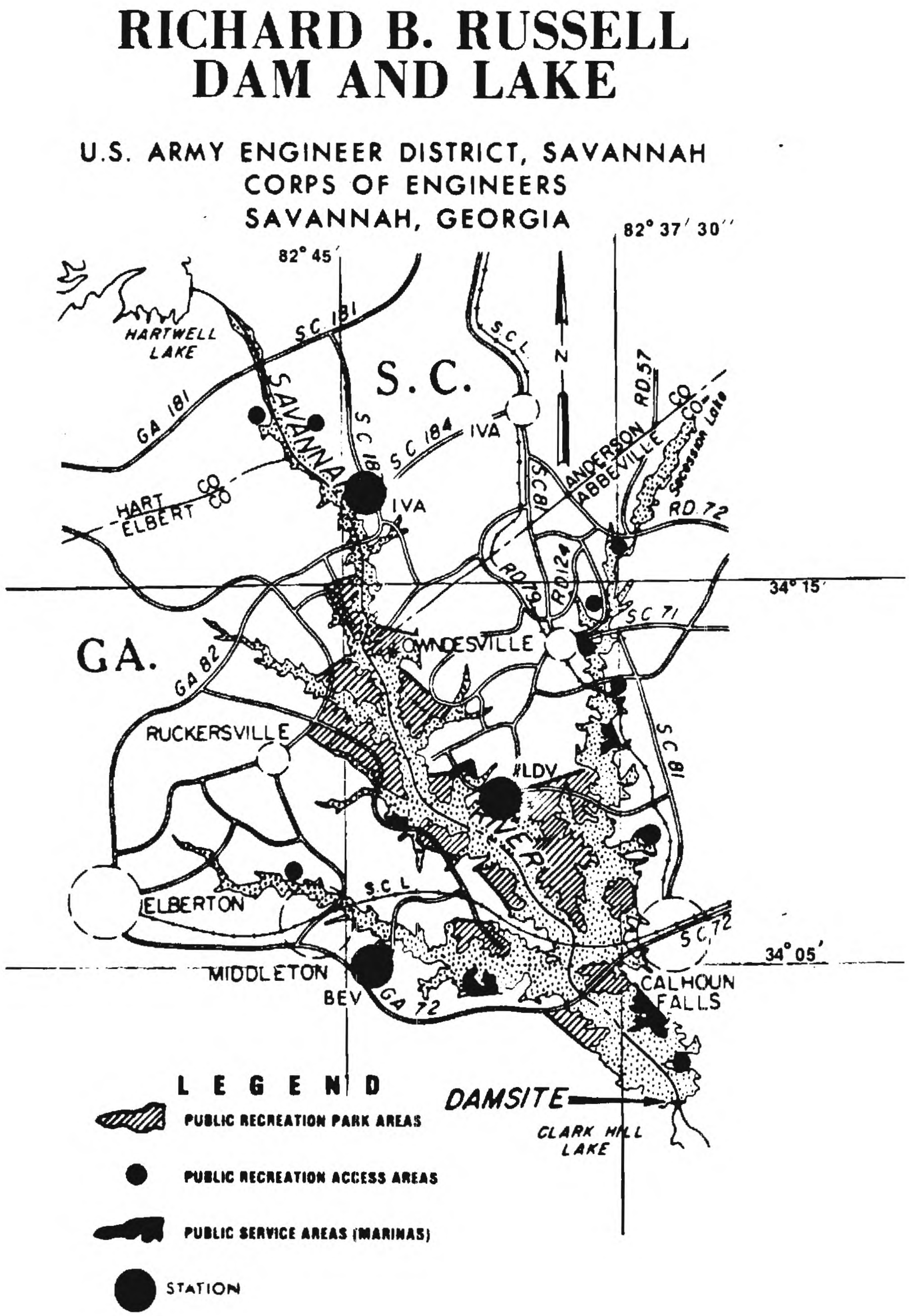


Figure 2. Location map for the three-station Richard B. Russell Lake Seismic Net

Savannah District Corps of Engineers. Georgia Tech and the Savannah District Corps of Engineers also agree to the mutual use of the microearthquake monitoring system in the area between Hartwell and Clark Hill Reservoirs. Use of the data is confined to non-profit research. Requests for the usage of the data can be submitted directly to Georgia Tech. However, Georgia Tech must forward all requests to the Savannah District Corps of Engineers for approval. A brief report describing the data usage, the seismic events, and copies of the appropriate events shall be submitted to the Savannah District Corps of Engineers.

The designation for the northernmost station is IVA because it is 8 km west-southwest of Iva, South Carolina. IVA is within 1.0 km of the Savannah River and 13 km southeast of Hartwell Lake. Station LDV is 8 km south-southwest of Lowndesville, South Carolina and 15 km northwest of the Richard B. Russell Dam site, at the head waters of Clark Hill Reservoir. Station BEV is near the former town of Beverly, Georgia, and 14 km west-northwest of the Dam site. Detailed descriptions of the locations of the three stations IVA, LDV, and BEV are given in Appendix I.

The regional distribution of seismic stations is shown in Figure 3. Station CHF is about 1.0 km east of the Richard B. Russell Dam site. Station CHF was funded by the Savannah District Corps of Engineers and eventually installed by the U.S. Geological Survey. The station consists of one vertical and one horizontal short-period seismometer. The data are telemetered to Columbia, South Carolina, where they are recorded on a helical recorder. Station PRM on Parsons Mountain is part of the South Carolina Seismic Net operated by the U.S.G.S. Stations EP1, CH5, and CH6 in the Clark Hill area are operated by Georgia Tech with the support of the Nuclear Regulatory Commission. At Georgia Tech, the Clark Hill stations are combined with the three Richard B. Russell stations to form a 75 km linear array and are recorded on a triggered magnetic tape system. Additional seismic coverage to the north is provided by station SMT operated by Duke Power and the University of South Carolina. To the south, the Savannah River Plant operates a three-station array. To the southeast, station MTT, operated by the U.S. Geological Survey, is part of the South Carolina Net.

INSTRUMENTATION

The components of the microearthquake monitoring system were provided by the Savannah District Corps of Engineers. The system was assembled and installed by Georgia Tech. The specifications and construction of the system were made uniform in order to provide uniform response characteristics.

A vault was constructed to house the instruments in the field (see Figure 4). The vault was designed to provide a 10 to 20 cm thick

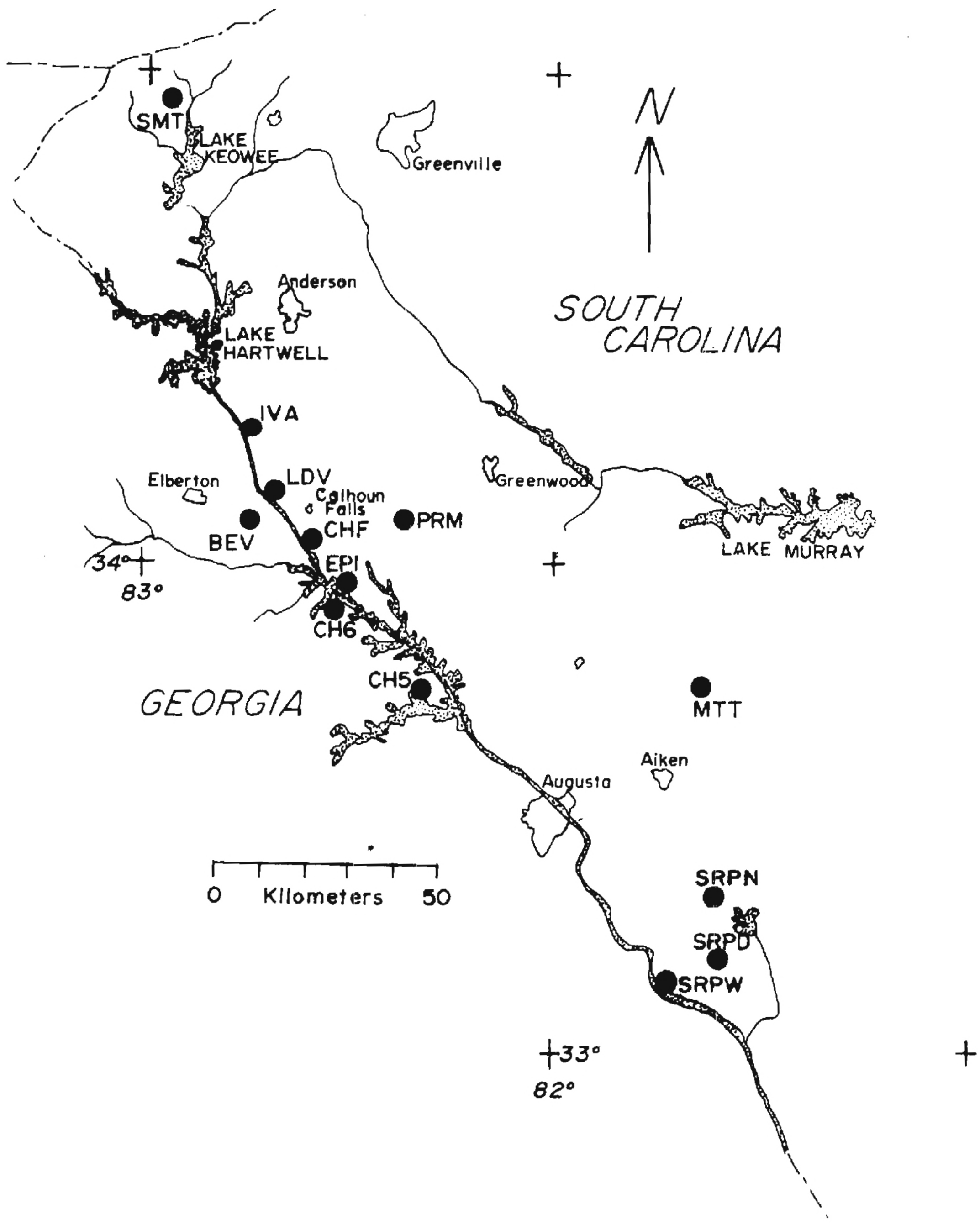
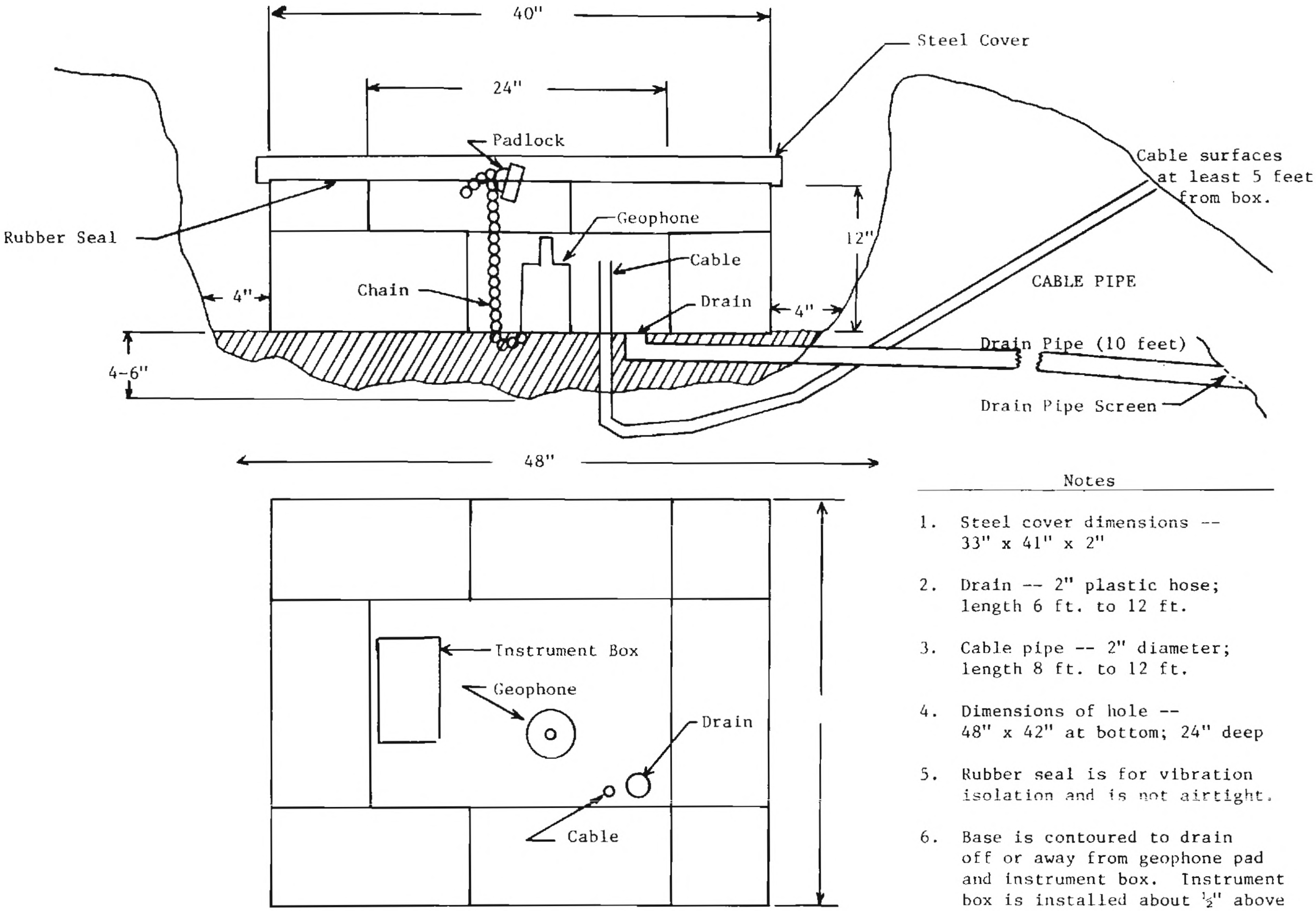


Figure 3. Location of seismic stations along the Savannah River



Notes

1. Steel cover dimensions -- 33" x 41" x 2"
2. Drain -- 2" plastic hose; length 6 ft. to 12 ft.
3. Cable pipe -- 2" diameter; length 8 ft. to 12 ft.
4. Dimensions of hole -- 48" x 42" at bottom; 24" deep
5. Rubber seal is for vibration isolation and is not airtight.
6. Base is contoured to drain off or away from geophone pad and instrument box. Instrument box is installed about ½" above concrete.

Figure 4. Specifications for the seismic vaults built for the Richard B. Russell Seismic Net

cement base on which to rest the geophone. Sites were chosen to allow placement of the cement pad as close to bedrock as possible, and on a sufficient slope to guarantee drainage. Cinder blocks were used to build the walls and the top was covered by a welded iron cover. The design provides for both drainage of water and circulation of air. The instruments are housed in separate weather-proof containers for their protection.

Figure 5 shows the assembly of instruments used in the field. Additional lightning protection circuitry has been designed and implemented in this system to help avoid damage. The frequency modulated signal is transmitted to Georgia Tech via commercial telephone lines. At Georgia Tech, (Figure 5b) the telephone line signal is conditioned for proper impedence matching for the discriminators. The discriminator bank is designed for plug-in expansion from the existing 3 to 7 possible stations. A patch cord system is used to route the discriminated signals to helical recorders. The timing system is connected to the timing system of the Georgia Tech networks and provides second, minute and 6-hour marks for the ink recorders. Event recording is accomplished by two analog tape recorders. The first runs continuously as a data delay loop inserting a seven-second delay into the signal. The second tape recorder is triggered by a pre-set threshold trace displacement and records the delayed signal. The second recorder runs for approximately 1.5 minutes for each trigger. A tape speed compensation tone and a time code on a 100-Hertz amplitude-modulated signal are recorded simultaneously.

DATA ANALYSIS

The objective of the data analysis is to review all records obtained from the microearthquake recording system and compute locations and magnitudes for earthquakes recorded by the system. Seismic activity occurring within the immediate vicinity of the reservoir, as defined by a 50 km radius from the Savannah River, will be reported to the Savannah District Corps of Engineers. Discrimination of earthquakes from local quarry blasts or construction explosions requires, in addition, that the principal active quarries be located and identified. Figure 6 defines the area of investigations and the currently identified sites of explosions.

The data analysis presented in this first annual report covers the time period from June 20, 1980, to January 31, 1981. During most of the initial recording period only two of the three stations were recording with several periods when only one station was recording. Only once for twenty days in January were all three stations operating simultaneously. The primary cause of the system failures has been from nearby lightning strikes.

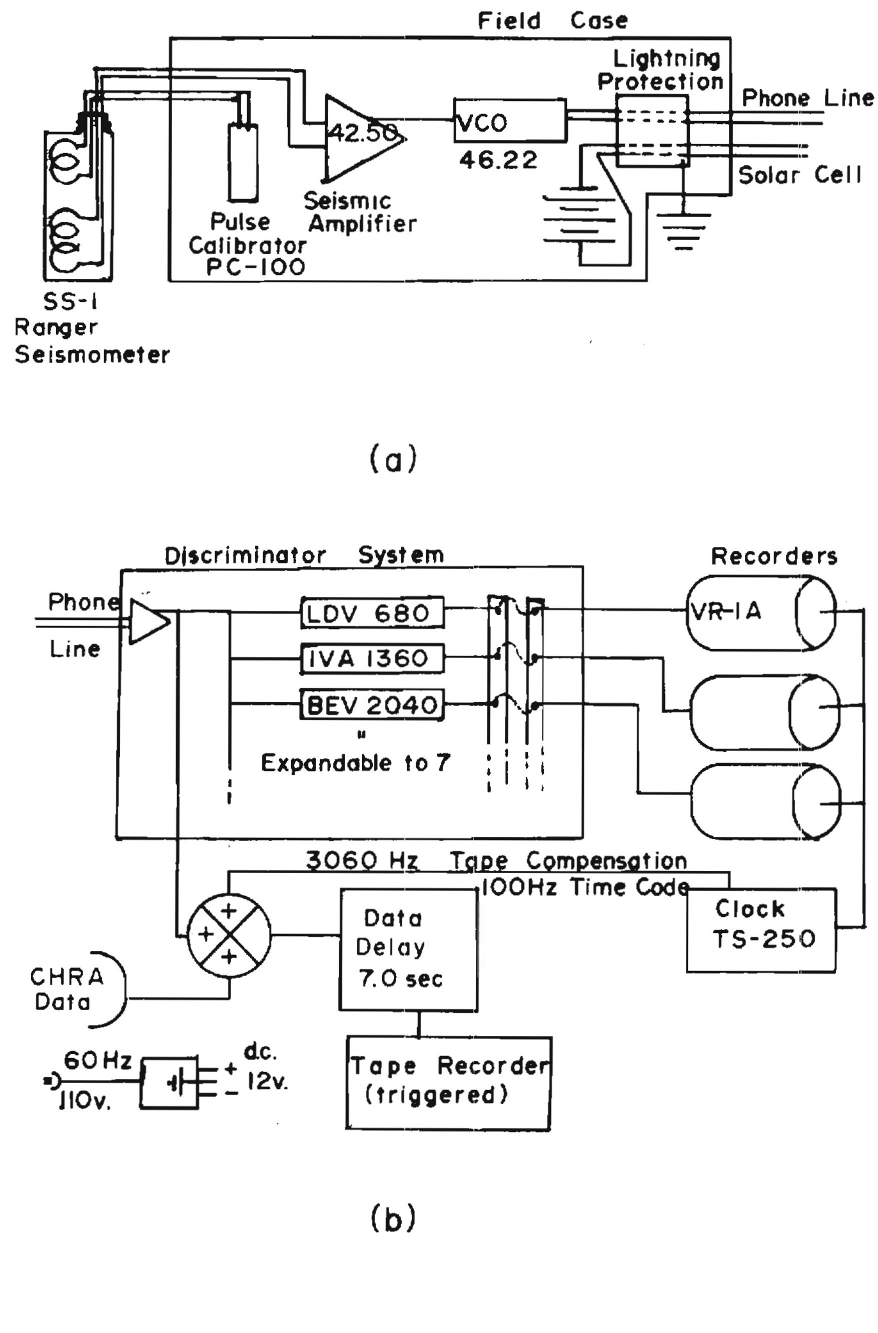


Figure 5. Instrumentation design of the Richard B. Russell Lake Seismic Net

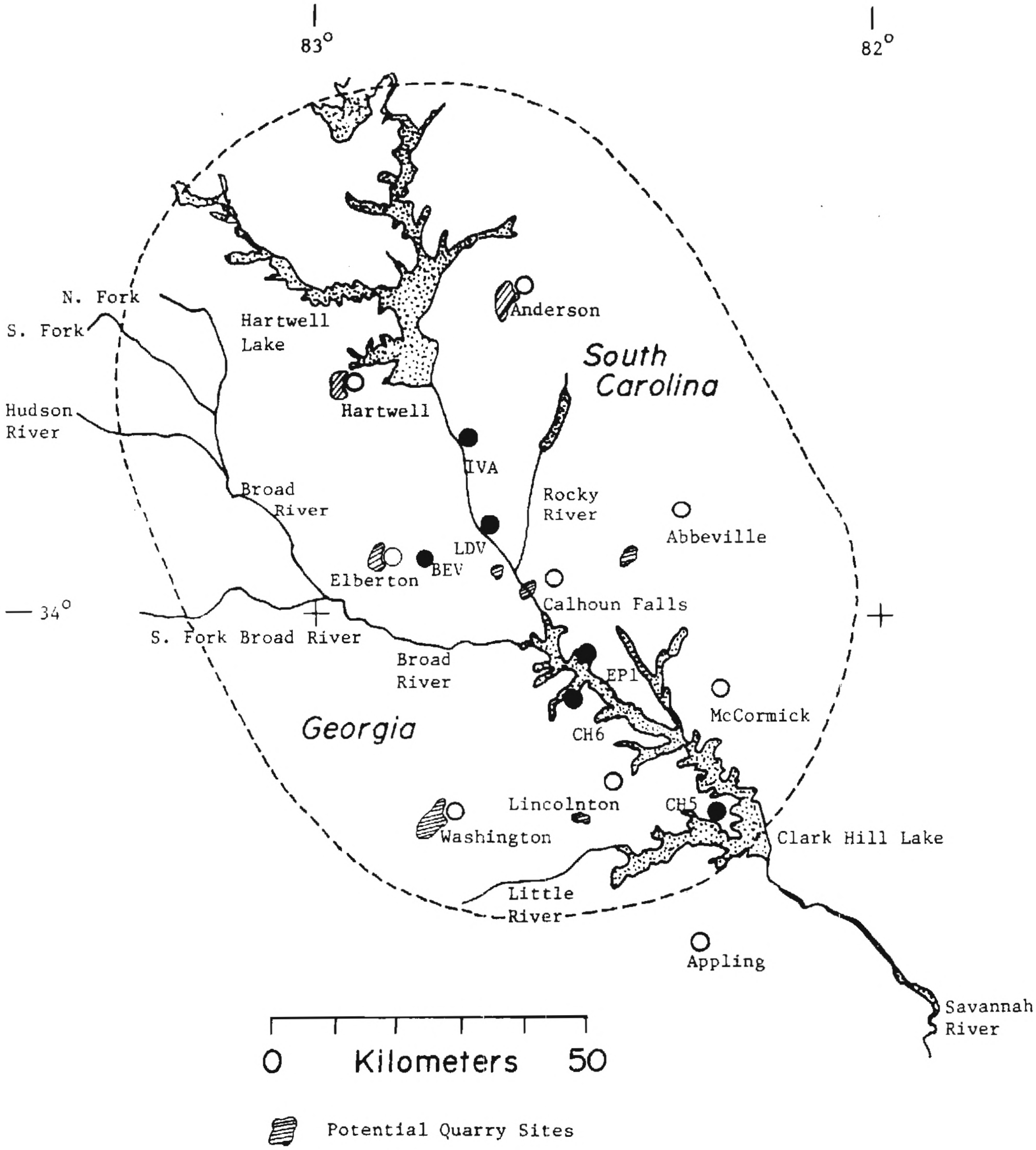


Figure 6. Area of investigation and locations of quarries active during the first period of operation of the Seismic Net

Table I - Station Operation Periods

	IVA	BEV	LDV	One-Station Coverage	Two-Station Coverage	Three-Station Coverage
June*	0%	36%	100%	64%	36%	0%
July	6%	100%	65%	29%	68%	3%
August	0%	71%	29%	52%	48%	0%
September	0%	0%	67%	67%	0%	0%
October	0%	100%	100%	0%	100%	0%
November	47%	43%	100%	10%	90%	0%
December	0%	71%	97%	32%	68%	0%
January	78%	97%	90%	0%	35%	65%

*June 20 through June 30

During the period 97 events were recorded within a fifty kilometer radius of the Savannah River in Richard B. Russell Lake vicinity. All the events were blasts and their epicenters were confined to nine locations. Three of the blast areas were road construction sites with one being a single blast on Route 72 between Calhoun Falls and Abbeyville, South Carolina. Another of these sites had only two blasts thirteen days apart in December and was located about six kilometers southeast of Heardmont, Georgia. The other site had thirteen blasts covering the period from June 25 to December 30 and was due to bridge construction on Route 72 over the Savannah River. Of the remaining blast areas, four are suspected quarries. All four had seven to twenty-three events spanning the entire coverage period. All four were located on the outskirts of towns: Elberton, Hartwell, and Washington in Georgia and Anderson in South Carolina. The last remaining site is the Clark Hill Reservoir Area. A total of twenty-six events originated in the Clark Hill Area spanning the period from June 27 to December 26. Of these events 13 were quarry blasts from a quarry in the Clark Hill area. The other 13 events are local Clark Hill area earthquakes.

Table II is a list of representative events, one from each blast site. The Clark Hill Reservoir Area events are listed in Table III. Events in the Clark Hill Reservoir Area consisted of quarry blasts and earthquakes from the epicentral area of the August 2, 1974, earthquake.

Table II - Representative Events from Blast Sites

Date	Station	Arrival Time	S - P	Location
27 Jun 80	LDV	21:15:56.6	5.2	Anderson, S. C.
29 Aug 80	BEV	21:15:57.6	5.5	
29 Aug 80	LDV	20;05:07.8	1.0	Savannah River
	BEV	20:05:07.9	1.2	
30 Oct 80	LDV	20:51:04.5	2.2	Elberton, Ga.
	BEV	20:51:04.0	1.6	
12 Nov 80	LDV	16:00:37.0	2.5	Hartwell, Ga.
	IVA	16:00:34.9	4.3	
15 Dec 80	LDV	17:06:39.4	0.8	Heardmont, Ga.
	BEV	17:06:39.9	0.6	
20 Jan 81	LDV	20:56:03.1	2.2	Route 72
	BEV	20:56:03.0	2.8	
	IVA	20:56:05.5	3.8	
24 Jan 81	LDV	20:51:39.6	2.3	Washington, Ga.
	BEV	20:51:39.2	2.0	
	IVA	20:51:42.0	4.0	

Table III - Clark Hill Reservoir Events

Date	Station	Arrival Time	S - P
06 Jul 80	LDV	07:35:51.8	2.8
	BEV	07:35:51.8	2.9
07 Jul 80	LDV	06:21:52.3	2.9
	BEV	06:21:52.0	2.7
18 Jul 80	BEV	23:31:08.8	2.9
19 Jul 80	BEV	12:09:15.4	2.9
31 Jul 80	LDV	16:01:23.3	3.2
	BEV	16:01:22.7	2.7
31 Jul 80	LDV	23:08:59.0	2.8
	BEV	23:08:58.9	2.8
18 Aug 80	LDV	13:18:12.3	2.8
	BEV	13:18:12.2	2.6
14 Oct 80	LDV	00:12:21.0	3.0
	BEV	00:12:21.0	2.9
18 Oct 80	LDV	00:41:50.6	2.8
	BEV	00:41:50.9	2.9
30 Oct 80	LDV	02:19:11.0	2.8
	BEV	02:19:10.8	3.0
02 Dec 80	LDV	20:14:24.5	3.1

Appendix I

Equipment assignment for IVA

Amplifier	419	VCO Frequency	1360
Pulse Calibrator	164	Gain	66dB
Geophone	766	Filter low cut	0.2 Hz
Recorder	390	Filter high cut	25 Hz

The location of the telephone pole is indicated in the map. It is numbered E-1-37.

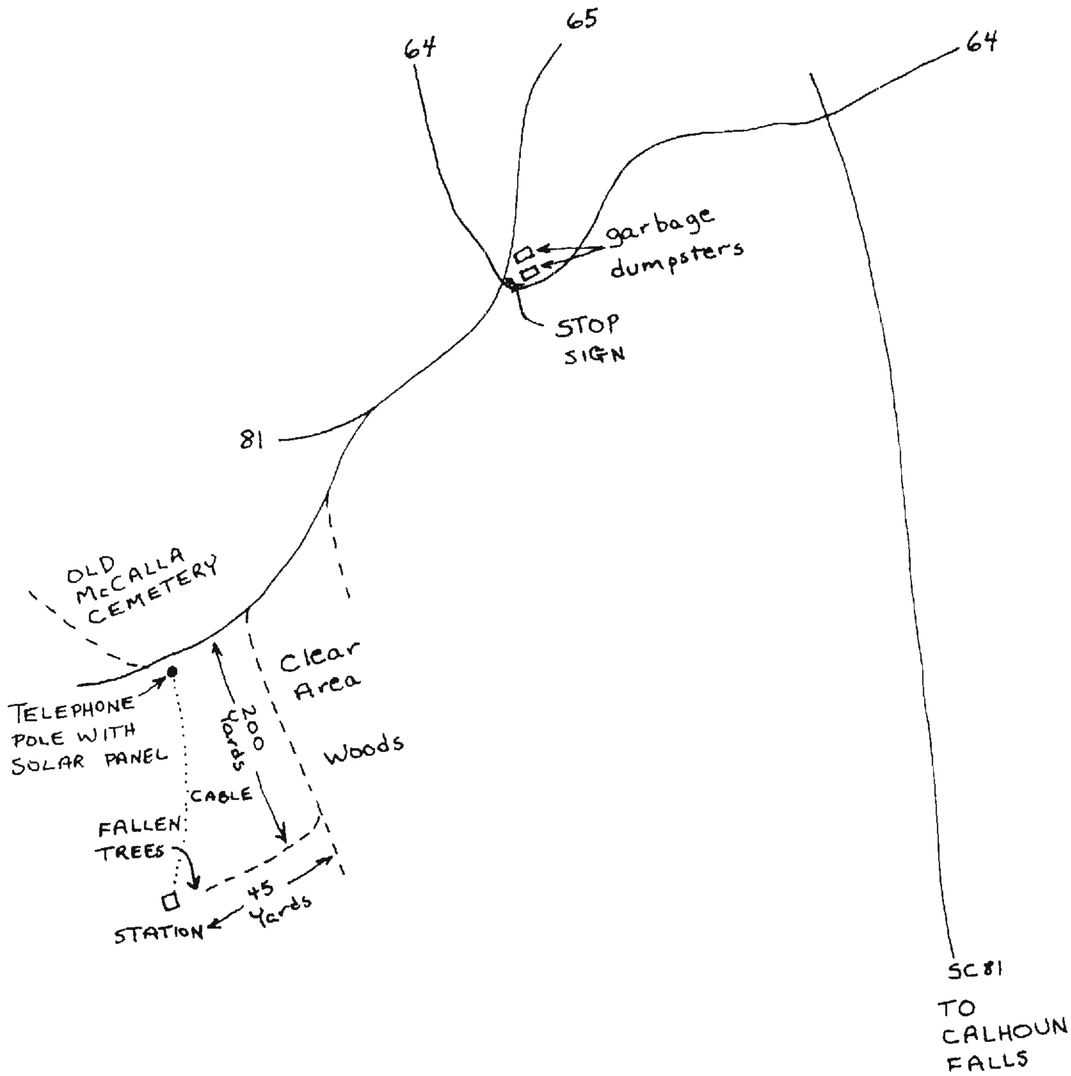
Vault Location

Latitude	34.2721 ^{o}N
Longitude	82.7460 ^{o}W
Elevation	0.1676 km

The property is owned by the U.S. Army Corps of Engineers.

Directions to IVA:

From downtown Elberton take N. Oliver Road toward South Carolina. This road intersects with Georgia 368. There is a Texaco station at the intersection. Take a right here. The road crosses the Savannah River and becomes S.C. 184. 184 forks into 184 and 187. Take the road to the left (187) and continue for 0.6 mile. A dirt road runs to the left here. Take it and turn right at the next dirt road. This road forks. Take the right fork. This will go to the edge of a hill. Look for a solar panel on a pine tree and follow the cable down the hill to the station.



Directions to IVA (cont.)

Equipment assignment for LDV

Amplifier	348	VCO Frequency	680
Pulse Calibrator	165	Gain	66dB
Geophone	768	Filter low cut	0.2 Hz
Recorder	386	Filter high cut	25 Hz

Location of telephone connection is as indicated on map.

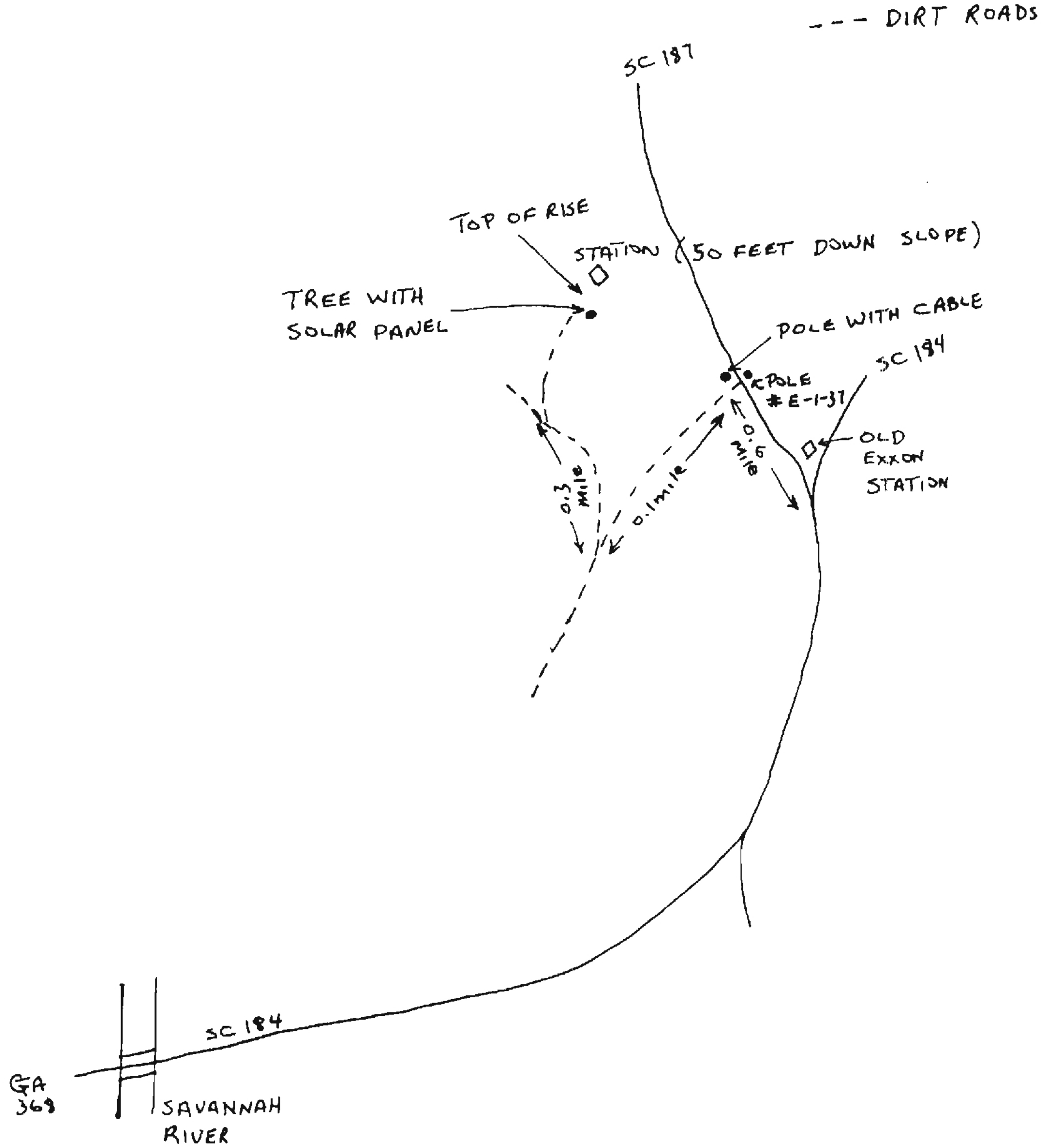
Vault Location

Latitude	34.148°N
Longitude	82.6833°W
Elevation	0.1615 km

The Property is owned by the U.S. Army Corps of Engineers.

Directions to LDV:

From Calhoun Falls take S.C. 81 north until it intersects with S.C. 64. Turn left onto 64 and cross the river (a future lake) and proceed to the stop sign. At the intersection turn left onto S.C. 65. Stay on 65 passing a fork to the right until the road forks into a dirt road to the left and a paved road to the right. This road runs through an open area of tall hardwood trees. Take the dirt road to the left that passes through these woods. Up this road about 200 yards another road which may be slightly overgrown runs to the right. Stop here, and follow the road through the woods on foot. The station is behind some fallen trees at the end of the road.



Directions to LDV (cont.)

Appendix I (Continued)

Equipment assignments for BEV

Amplifier	306	VCO Frequency	240
Pulse Calibrator	163	Gain	66dB
Geophone	767	Filter low cut	0.2 Hz
Recorder	391	Filter high cut	25 Hz

Location of telephone pole

Proceed north on Georgia Highway 245 from Georgia 72. The cable is tied to a pole as indicated on the site map. The pole is numbered #8P and is between the third and fourth power pole from the dumpster.

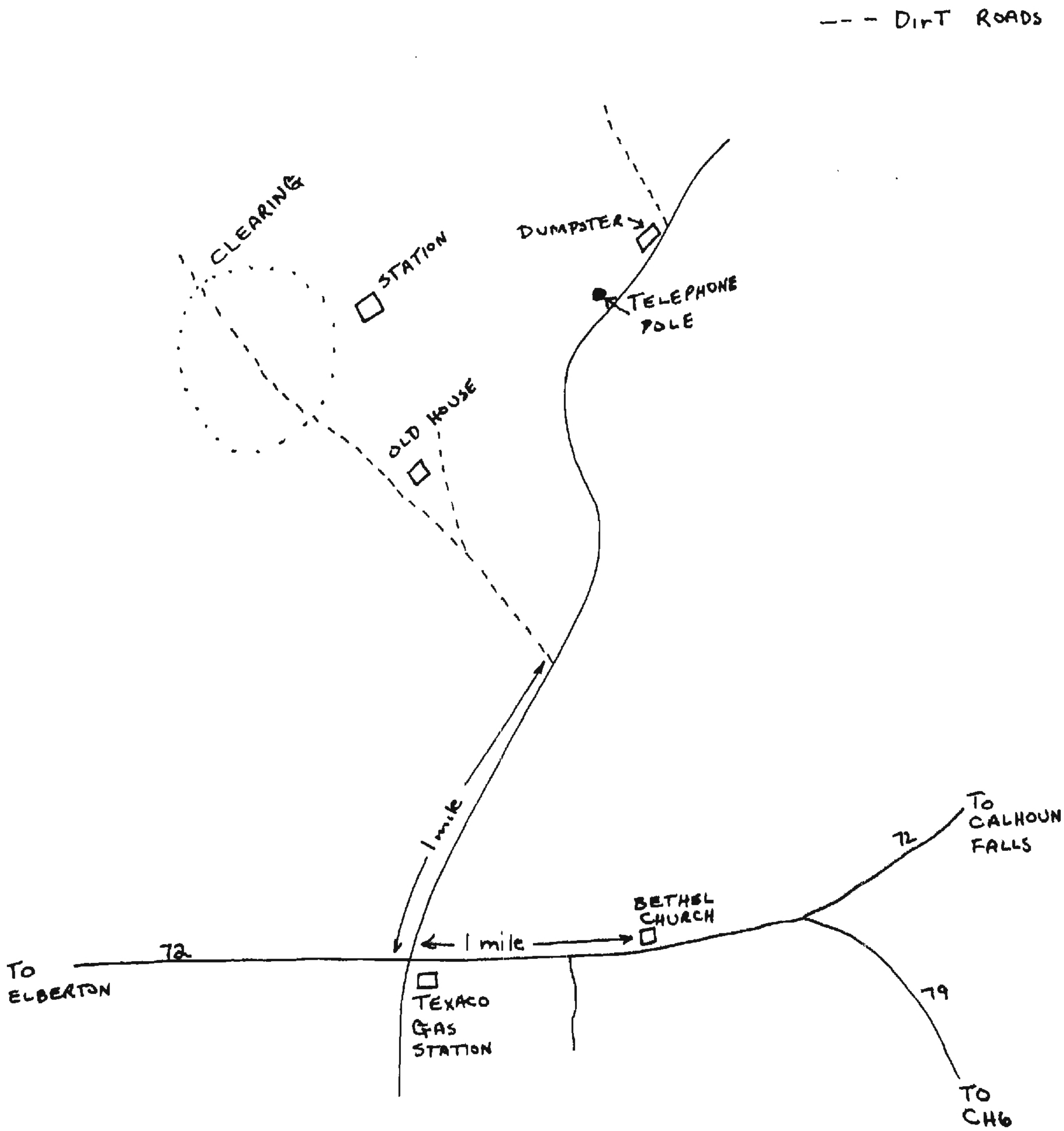
Vault Location

Latitude	34.0893°N
Longitude	82.7334°W
Elevation	0.1584 km

The property is owned by the U.S. Army Corps of Engineers.

Directions to BEV:

From Elberton take Highway 72 westward through Middleton. There will be a Texaco station and a mini-market on the right. Make a left turn at the Texaco station. Take this road for about 0.95 miles. Take the dirt road here which forks to the left. This road will in turn fork to the right and left. Take the left fork. This road will run through a clearing about 100 yards in diameter. The station is on the right side about 50 feet from the edge of the open area.



Directions to BEV (cont.)